# 4 TECHNOLOGY APPLICATIONS ANALYSIS

This section of the report describes the general applicability of the E-Beam technology, operated by Haley and Aldrich, for treating contaminated groundwater at hazardous waste and petroleum release sites. The analysis is based primarily on the demonstration results at the NBVC; however, the demonstration results are supplemented by data from other applications of the E-Beam technology, including a study conducted in Germany with the E-Beam system and a demonstration conducted at the U.S. Department of Energy Savannah River Site in Aiken, South Carolina under the EPA Superfund Innovative Technology Evaluation (SITE) demonstration program (EPA 1997). Vendor's claims regarding the effectiveness and applicability of the E-Beam technology are included in Appendix A.

This section also discusses the following topics regarding the applicability of the E-Beam technology: technology performance versus ARARs, technology operability, key features of the treatment technology, applicable wastes, availability and transportability of equipment, material handling requirements, range of suitable site characteristics, limitations of the technology, and potential regulatory requirements.

## 4.1 TECHNOLOGY PERFORMANCE VERSUS ARARS

The technology's ability to comply with existing federal, state, or local ARARs (for example, MCLs) should be determined on a site-specific basis, as is the case with all innovative technologies. The discussion below focuses on the demonstration at the NBVC for MtBE-contaminated groundwater.

For the demonstration at the NBVC, ARARs were identified and established by consensus among the stakeholders for the technology demonstration. ARARs included EPA and California Primary and Secondary MCLs as well as California Action Levels and Public Health Goals for drinking water. The contaminants initially present in the groundwater were of primary concern; these included MtBE and BTEX. Partially oxidized organics from MtBE degradation (tBA, acetone, aldehydes, glyoxals) were also of concern. In addition, several drinking water variables were identified as applicable if the effluent was to be used as a drinking water supply. These drinking water variables included bromate, a by-product of chemical oxidation, and potential by-products of subsequent chlorination, including total TTHM and HAA. For the by-products of subsequent chlorination, the applicable criteria are described in the proposed Stage 2 DBPR. These requirements have been proposed in a Notice of Agreement in Principle dated December 20, 2000 (65 FR 251, pages 83015-83024).

In the demonstration at the NBVC, the E-Beam technology met the treatment goals for the primary contaminants of concern. However, reaction by-products from MtBE, BTEX and other constituents of gasoline (tBA, acetone, aldehydes, and glyoxals) remained in the effluent and were higher in concentration than some potentially applicable ARARs. Also, the technology did not meet the drinking water requirements relating to TTHMs and HAAs in SDS testing of the effluent. In the Phase 2 studies where a dose response was developed, it is likely that, if a slightly higher dose had been chosen (about 2,000 krads), tBA would have been below the action level. Because the other reaction by-products (acetone, aldehydes, and glyoxals) were not determined, it is not clear whether they would have met the target treatment concentrations.

The results of the previous demonstration of the E-Beam system at the Savannah River Site provided information with respect to chlorinated hydrocarbon contaminants in groundwater. During the demonstration, the E-Beam system treated about 70,000 gallons of groundwater contaminated with VOCs, including TCE and PCE, which were present at concentrations of about 27,000 and 11,000 µg/L, respectively. The groundwater also contained low levels (40 µg/L) of cis-1,2-dichloroethene (1,2-DCE). Other commonly encountered groundwater contaminants, including BTEX and other chlorinated hydrocarbons, were spiked into the influent during part of the demonstration at levels of 500 to 1,000 µg/L. The E-Beam system achieved the effluent target levels for 1,2-DCE, carbon tetrachloride, and BTEX; however, effluent target levels were not achieved for TCE, PCE, 1,1,1-trichloroethane, 1,2-dichloroethane, and chloroform. The results from bioassay tests indicate that treatment by the E-Beam technology increased groundwater toxicity to fathead minnows but not to water fleas.

In summary, the E-Beam technology has been shown to be capable of destroying many commonly encountered organic contaminants in groundwater to below applicable drinking water regulatory criteria in California. For hydrocarbons, including BTEX and MtBE, effluent compliance with these criteria appears to be well within the capabilities of the technology. At high concentrations of chlorinated hydrocarbons, problems may be encountered if MCLs are established as the effluent requirements. Additionally, partially oxidized organic compounds and other chemical oxidation by-products may be of concern to ARAR compliance at specific sites, depending on the application and the planned disposal or reuse of the effluent from the E-Beam system. Future ARARs relating to these types of contaminants are being contemplated and may take the form of either chemical specific or bioassay requirements.

The following were identified as additional potential technology performance issues with respect to ARARs:

- The technology's ability to meet any future chemical-specific ARARs for by-products should be considered because of the potential for formation of partially oxidized organic compounds during treatment. Properly designed pilot testing will define variables to be considered.
- The technology's ability to meet any state or local requirements such as passing bioassay tests should be considered because of the potential for treatment by-product formation. Properly designed pilot testing will define variables and alternatives for meeting all of the local, state and federal requirements.
- States require notification and registration for system operation
- Design, construction, operation, and maintenance of the system must comply with general radiation exposure regulations, Over 500 accelerators exist in the US, and all of the States have regulations in place that specify operation. Examples of applications are medical device sterilization and, more recently, food irradiation facilities.

## 4.2 TECHNOLOGY OPERABILITY

Operating variables are those variables that can be varied during the treatment process to achieve desired removal efficiencies and treatment goals. The principal factor affecting E-Beam system performance is the E-Beam dose. The dose can be varied, within the equipment limits of each accelerator, by varying the beam current (in the demonstration system it was variable from 0 - 42 mA) and water flow rate (in the demonstration system it was variable from 5 - 40 gpm). Therefore, dose depends on E-Beam power and water flow rate.

In a typical continuous flow treatment system, the absorbed dose can be determined by measuring the temperature difference of the water stream before and after irradiation. The relationship is derived for pure water by the following relationships:

$$1 \text{ rad} = 100 \text{ erg g}^{-1} \text{ (or 1 Mrad} = 1.0 \times 10^{8} \text{ erg g}^{-1}) \qquad [2]$$

substituting in,

$$1 \text{ erg} = 2.39 \times 10^{-8} \text{ cal} \qquad [3]$$

then,

$$1 \text{ Mrad} = 2.39 \text{ cal g}^{-1} \qquad [4]$$

converting to °C,

$$1 \text{ Mrad} = 2.39°\text{C} = 10 \text{ kGy} \qquad [5]$$

or,

$$°T = 0.418 \text{ Mrad or } 4.18 \text{ kGy } °C^{-1} \qquad [6]$$

The relationship between dose and temperature is one way to estimate relative energy consumed for the treatment of a compound(s). It provides an estimate of the temperature increase in the treated solution, and this can then be related to energy (and cost) for the treatment. As the beam current passes through a tungsten wire filament within the electron accelerator, a stream of electrons is emitted that comprises the E-Beam. The number of electrons emitted per unit time is proportional to the beam current. Therefore, for a given flow rate, dose is increased by increasing the beam current, which increases the number of electrons impacting the liquid and, consequently, the number of reactive species formed. The electron accelerator in the E-Beam system used for the demonstration is capable of generating a maximum beam current of about 42 mA. The beam current is adjusted and monitored at the control panel in the E-Beam trailer control room.

Flow rate through the treatment system determines the length of time the water is exposed to the E-Beam. In general, increasing the exposure time (decreasing the flow rate) improves treatment efficiency by increasing the number of reactive species formed as more high-speed electrons impact a discrete volume of water. If treatment goals are not met, increasing the beam current or adjusting the influent delivery system can improve treatment efficiency. The flow rate provided by the influent pump is monitored and adjusted in the E-Beam trailer pump room.

The voltage applied to the E-Beam affects the depth to which the E-Beam penetrates the water being treated. At a given E-Beam penetration depth, the portion of flowing water directly irradiated by the beam depends on the thickness of the flowing water. Adjusting the influent delivery system for the E-Beam unit can control the thickness of the flowing water. The internal components of the delivery system and its dimensions are proprietary information.

## 4.3 KEY FEATURES OF THE TREATMENT TECHNOLOGY

Common methods for treating groundwater contaminated with organic compounds include air stripping, steam stripping, carbon adsorption, biological treatment, and chemical oxidation. As regulatory requirements for secondary wastes and treatment by-products become more stringent and more expensive to comply with, technologies involving free radical chemistry offer a major advantage over other treatment techniques: these technologies destroy contaminants rather than transfer them to another medium, such as activated carbon or the ambient air. Technologies involving free radical chemistry offer faster reaction rates than other technologies, such as some biological treatment processes. According to the published literature (Buxton et al., 1988), the entire sequence of reactions between organic compounds and reactive species occurs in the area where the E-Beam impacts the water and is completed in milliseconds.

The E-Beam technology generates strong reducing species ($e^{-}_{aq}$ and •H) and strong oxidizing species (•OH) simultaneously and in approximately equal concentrations. Because three reactive species are formed, multiple mechanisms or chemical pathways for organic compound destruction are provided. In this way, the E-Beam technology differs from other technologies that involve free radical chemistry. Such technologies typically rely on a single organic compound destruction mechanism, usually one involving •OH.

The E-Beam system does not generate residue, sludge, or spent media that require further processing, handling, or disposal. Most of the target organic compounds are either mineralized or broken down into low molecular weight compounds. Radicals generated by the E-beam react with contaminants to produce intermediate species that are ultimately oxidized to $CO_2$, water, and salts. However, incomplete oxidation results in formation of low molecular weight aldehydes, glyoxals, organic acids, and SVOCs, one of which is tBA. If the MtBE concentration in the water being treated is high enough, then tBA production from MtBE oxidation by E-beam might render the effluent non-compliant with tBA objectives.

### 4.4 APPLICABLE WASTES

Based on the NBVC and Savannah River Site demonstration results, as well as results from other case studies and published accounts of studies conducted at up to 120 gpm, the E-Beam technology may be used to treat various VOCs and SVOCs in liquids, including groundwater (with solids content of up to 5 %), wastewater, biosolids, drinking water, and landfill leachate. Where stringent effluent requirements apply, the technology appears to be particularly applicable to the treatment of contaminated groundwater and wastewater containing petroleum hydrocarbons. However, the technology can achieve substantial reductions in the concentrations of other organic compounds. The following is a partial listing of various solutions with one or more organic contaminants:

1. General organic compounds (Kurucz et al., 1991a; 1991b)
2. BTEX (Nickelsen et al., 1992; 1994; Zele et al., 1998
3. THMs, dichloromethane, and carbon tetrachloride (Mak et al., 1996; 1997)
4. Phenol (Lin et al., 1995)
5. Naphthalene ( Cooper et al., 2002)
6. Alternative Fuel Oxygenates (Mezyk et al., 2001)
7. Chemical Warfare Agent-Simulants (Nickelsen et al., 1998)

### 4.5 AVAILABILITY AND TRANSPORTABILITY OF EQUIPMENT

Haley and Aldrich provides the complete E-Beam treatment system configured for site-specific conditions. All E-Beam treatment equipment is leased to the client. As a result, all depreciation and salvage value is incurred by Haley and Aldrich, which is reflected in the price for leasing the equipment. At the end of a treatment project, Haley and Aldrich decontaminates and demobilizes its treatment equipment. Haley and Aldrich assumes that this equipment will operate for the duration of the groundwater remediation project and will still function after the remediation is complete as a result of routine maintenance and modifications.

Currently, only one mobile treatment system has been constructed and is available through Haley and Aldrich for application to site-specific requirements. However, for larger remediation projects, it is more cost effective to construct a fixed treatment system at the site.

## 4.6 MATERIALS HANDLING REQUIREMENTS

Other than the spent filter media when pretreatment processing is used in the influent delivery system, the E-Beam system does not generate treatment residuals, such as sludge, that requires further processing, handling, or disposal. The E-Beam unit and the other components of the system produce no air emissions that require specific controls. Pretreatment processing typically involves cartridge or sand filters to remove suspended solids. Spent filter media or other residuals from these systems should be dewatered, containerized, and analyzed to determine whether they should be disposed of as hazardous or non-hazardous waste.

Treated water may be disposed of either on or off site, depending on site-specific requirements and limitations. Examples of on-site disposal options for treated water include groundwater recharge or temporary on-site storage for sanitary use. Examples of off-site disposal options include discharge into surface water bodies, storm sewers, and sanitary sewers. Bioassay tests may be required in addition to routine chemical and physical analyses before the treated water is disposed of.

## 4.7 RANGE OF SUITABLE SITE CHARACTERISTICS

In addition to feed waste characteristics and effluent discharge requirements, site characteristics and support requirements are important when considering the E-Beam technology. Site-specific factors can impact the application of the E-Beam technology, and these factors should be considered before selecting the technology for remediation of a specific site. Site-specific factors addressed in this section include site support requirements and utility requirements.

According to Haley and Aldrich, both transportable and permanently installed E-Beam systems are available (see Section 5, Technology Status, and Appendix A, Vendor's Claims for the Technology). The support requirements for these systems are likely to vary. This section presents support requirements based on the information collected for the trailer-mounted system used during the demonstration.

### 4.7.1 Site Support Requirements

The site must be accessible for a tractor-trailer truck with an 8-foot by 48-foot trailer weighing about 35 tons. An area of 8 feet by 48 feet must be available for the trailer that houses the E-Beam system, and additional space must be available to allow personnel to move freely around the outside of the trailer. The area containing the E-Beam trailer should be paved or covered with compacted soil or gravel to prevent the trailer from sinking into soft ground. The trailer is equipped with a 500-gallon influent holding tank and an effluent holding tank with a capacity of about 100 gallons, but space outside the trailer may be required for additional influent and effluent holding tanks if more holding capacity is needed. An additional area may be required for an office or laboratory building or trailer. During the demonstration, an area of about 100 feet by 200 feet was used for the E-Beam trailer, an outdoor staging area, and miscellaneous equipment.

The E-Beam trailer is equipped with influent and effluent ports on the exterior trailer wall. The influent port is plumbed to an influent pump in the pump room that is rated for a maximum flow rate of 40 gpm, and the effluent port is plumbed from the effluent holding tank. Plumbing must be provided to the influent port from the groundwater well or other feed waste source and from the effluent port to the discharge point.

### 4.7.2 Utility Requirements

The E-Beam system may be operated using 480-volt, 3-phase electrical service. The E-Beam trailer is also equipped with a diesel-powered generator that allows the system to be operated without an external electrical source. Additional electrical service may be needed to operate groundwater extraction well pumps, light office and laboratory buildings, and on-site office and laboratory equipment, as applicable. Haley and Aldrich maintains and services its E-Beam systems; therefore, no inventory of spare parts is required.

## 4.8 LIMITATIONS OF THE TECHNOLOGY

Three limiting factors have been identified based on the operation of the Haley and Aldrich demonstration unit: limited operating flow rates, by-product formation, and operational problems associated with suspended solids in the influent. System operation is limited by the minimum and maximum flow rates at which a single unit can be operated. If treatment goals are not met while the system operates at the minimum flow rate and at maximum beam current, the dose cannot be further increased to improve system performance. Such a case would require operating additional E-Beam units in series, obtaining a larger E-Beam unit, or adding pretreatment or post-treatment, any of which would increase space requirements and costs. According to Haley and Aldrich, the demonstration unit was configured for a maximum flow rate of 40 gpm. Treatment at a higher flow rate would require modifying the influent delivery system for the unit, operating additional units in parallel, or obtaining a larger unit rated for a greater maximum flow rate; the latter two options would increase space requirements and costs. Based on research studies performed by Haley and Aldrich and demonstration results, toxic by-products are formed when water containing VOCs is treated by the E-Beam system. If by-products are a concern at a particular site, the E-Beam system would need to be operated in such a way that by-product formation would be reduced to acceptable levels. A third limiting factor involves the presence of suspended solids in the influent. Fine suspended solids not captured by the strainer basket might clog the influent delivery system for the E-Beam unit.

## 4.9 POTENTIAL REGULATORY REQUIREMENTS

This section discusses regulatory requirements pertinent to use of the E-Beam technology at Superfund and RCRA corrective action sites. The regulations applicable to implementation of this technology depend on site-specific remediation logistics and the type of contaminated liquid being treated; therefore, this section presents a general overview of the types of federal regulations that may apply under various conditions. State requirements should also be considered; because these requirements vary from state to state, they are not presented in detail in this section.

Depending on the characteristics of the liquid to be treated, pretreatment or post-treatment may be required for the successful operation of the E-Beam system. For example, solids may need to be filtered before treatment; a strainer basket was used to remove particulates larger than 0.045 inch during the demonstration. Each pretreatment or post-treatment process might involve additional regulatory requirements that would need to be determined in advance. No direct air emissions or residuals (such as sludge) are generated by the E-beam treatment process. Condensate is generated from the cooling air when it enters the air chiller, but Haley and Aldrich states that this liquid can be recirculated through the system. Therefore, only regulations addressing contaminated liquid storage, treatment, and discharge; potential fugitive air emissions; and additional considerations are discussed below.

### 4.9.1 Resource Conservation and Recovery Act

RCRA, as amended by the Hazardous and Solid Waste Amendments of 1984, regulates management and disposal of municipal and industrial solid wastes. EPA and RCRA-authorized states (listed in 40 Code of Federal Regulations [CFR] Part 272) implement and enforce RCRA and state regulations. Some of the RCRA requirements under 40 CFR Part 264 generally apply at Comprehensive Emergency Response, Compensation, and Liability Act (CERCLA) sites that contain RCRA hazardous waste because remedial actions generally involve treatment, storage, or disposal of hazardous waste.

According to Haley and Aldrich, the E-Beam system can treat liquid contaminated with most organic compounds, including solvents, pesticides, PAHs, and petroleum hydrocarbons. Contaminated liquid treated by the system may be classified as a RCRA hazardous waste or may be sufficiently similar to a RCRA hazardous waste that RCRA regulations will be applicable requirements.

### 4.9.2 Clean Water Act

The Clean Water Act (CWA) is designed to restore and maintain the chemical, physical, and biological quality of navigable surface waters by establishing federal, state, and local discharge standards. If treated liquid is discharged to surface water bodies or publicly owned treatment works (POTW), CWA regulations apply. On-site discharges to surface water bodies must meet substantive National Pollutant Discharge Elimination System (NPDES) requirements but do not require an NPDES permit. A direct discharge of (CERCLA) wastewater would qualify as "onsite" if the receiving water body is in the area of contamination or in close proximity to the site, and if the discharge is necessary to implement the response action. Off-site discharges to a surface water body require a NPDES permit and must meet NPDES permit limits. Discharge to a POTW is considered to be an off-site activity, even if an on-site sewer is used. Therefore, compliance with substantive and administrative requirements of the National Pretreatment Program is required in such a case. General pretreatment regulations are included in 40 (CFR) Part 403.

Any applicable local or state requirements, such as local or state pretreatment requirements or water quality standards (WQS), must also be identified and satisfied. State WQS are designed to protect existing and attainable surface water uses (for example, recreation and public water supply). WQS include surface water use classifications and numerical or narrative standards (including effluent toxicity standards, chemical-specific requirements, and bioassay requirements to demonstrate no observable effect level [NOEL] from a discharge) (EPA, 1988a). These standards should be reviewed on a state- and location-specific basis before discharges are made to surface water bodies.

### 4.9.3 Safe Drinking Water Act

The Safe Drinking Water Act (SDWA), as amended in 1986, required EPA to establish regulations to protect human health from contaminants in drinking water. EPA has developed the following programs to achieve this objective: (1) a drinking water standards program, (2) an underground injection control program, and (3) sole-source aquifer and well-head protection programs.

SDWA primary (or health-based) and secondary (or aesthetic) MCLs generally apply as clean-up standards for water that is, or may be, used as drinking water. In some cases, such as when multiple contaminants are present, more stringent maximum contaminant level goals (MCLG) may be appropriate. In other cases, alternate concentration limits (ACL) based on site-specific conditions may be applied. CERCLA and RCRA standards and guidance should be used in establishing ACLs (EPA 1987a). During the SITE demonstrations, Haley and Aldrich treatment system performance was tested for compliance with SDWA MCLs for several critical VOCs.

The underground injection control program regulates water discharge through injection wells. Injection wells are categorized as Classes I through V, depending on their construction and use. Reinjection of treated water involves Class IV (reinjection) or Class V (recharge) wells and should meet SDWA requirements for well construction, operation, and closure. If the groundwater treated is a RCRA hazardous waste, the treated groundwater must meet RCRA Land Disposal Restriction (LDR) treatment standards (40 CFR Part 268) before reinjection.

The sole-source aquifer and wellhead protection programs are designed to protect specific drinking water supply sources. If such a source is to be remediated using the E-Beam system, appropriate program officials should be notified, and any potential regulatory requirements should be identified. State groundwater anti-degradation requirements and WQS may also apply.

### 4.9.4 Clean Air Act

The Clean Air Act (CAA), as amended in 1990, regulates stationary and mobile sources of air emissions. CAA regulations are generally implemented through combined federal, state, and local programs. The CAA includes chemical-specific standards for major stationary sources that would not be applicable but could be relevant and appropriate for E-Beam system use. For example, the E-Beam system would usually not be a major source as defined by the CAA, but it could emit ozone , which is a criteria pollutant under the CAA's National Ambient Air Quality Standards (NAAQS). Therefore, the E-Beam system may need to be controlled to ensure that air quality is not impacted. This would be particularly pertinent in localities that are "non-attainment" areas for ozone . The National Emission Standards for Hazardous Air Pollutants (NESHAP) could also be relevant and appropriate if regulated hazardous air pollutants are emitted and if the treatment process is considered sufficiently similar to one regulated under these standards. In addition, New Source Performance Standards (NSPS) could be relevant and appropriate if the pollutant emitted and the E-Beam system are sufficiently similar to a pollutant and source category regulated by an NSPS. Finally, state and local air programs have been delegated significant air quality regulatory responsibilities, and some have developed programs to regulate toxic air pollutants (EPA 1989). Therefore, state air programs should be consulted regarding E-Beam treatment technology installation and use.

### 4.9.5 Toxic Substances Control Act

Testing, pre-manufacture notification, and record-keeping requirements for toxic substances are regulated under the Toxic Substances Control Act (TSCA). TSCA also includes storage requirements for polychlorinated biphenyls (PCB) (see 40 CFR §761.65). The E-Beam system may be used to treat liquid contaminated with PCBs, and TSCA requirements would apply to pretreatment storage of PCB-contaminated liquid.

### 4.9.6 Mixed Waste Regulations

As defined by the Atomic Energy Act (AEA) and RCRA, mixed waste contains both radioactive and hazardous components. Such waste is subject to the requirements of both acts. However, when application of both AEA and RCRA regulations results in a situation that is inconsistent with the AEA (for example, an increased likelihood of radioactive exposure), AEA requirements supersede RCRA requirements (EPA 1988a). Use of the Haley and Aldrich E-Beam system at sites with radioactive contamination might involve treatment or generation of mixed waste.

Office of Solid Waste and Emergency Response (OSWER), in conjunction with the NRC, has issued several directives to assist in identification, treatment, and disposal of low-level radioactive, mixed waste. Various OSWER directives include guidance on defining, identifying, and disposing of commercial, mixed, low-level radioactive and hazardous waste (EPA 1987b). If the Haley and Aldrich system is used to treat low-level mixed waste, these directives should be considered. If high-level mixed waste or transuranic mixed waste is treated, internal DOE orders should be considered when developing a protective remedy (DOE 1988). The SDWA and CWA also contain standards for maximum allowable radioactivity levels in water supplies.

### 4.9.7 Occupational Safety and Health Act

OSHA regulations in 29 CFR Parts 1900 through 1926 are designed to protect worker health and safety. Both Superfund and RCRA corrective actions must meet OSHA requirements, particularly §1910.120, Hazardous Waste Operations and Emergency Response. Part 1926, Safety and Health Regulations for Construction, applies to any on-site construction activities. For example, electric utility hookups for the Haley and Aldrich E-Beam system must comply with Part 1926, Subpart K, Electrical. Product chemicals, such as sulfuric acid and sodium hydroxide, if used with the E-Beam system, must be managed in accordance with OSHA requirements (for example, Part 1926, Subpart D, Occupational Health and Environmental Controls, and Subpart H, Materials Handling, Storage, and Disposal). Any more stringent state or local requirements must also be met. In addition, health and safety plans for site remediation should address chemicals of concern and include monitoring practices to ensure that worker health and safety are maintained.

## 4.10 Additional Considerations

The Haley and Aldich system generates a high-energy stream of electrons (ionizing radiation). These electrons are primarily directed to a contaminated liquid stream. However, some other radiation (x-ray) is generated when stray electrons hit metal components of the system. Therefore, regulations covering radiation-generating equipment could be considered ARARs. At the Savannah River Site, DOE regulations for radiation-generating equipment were applied. However, the Haley and Aldrich system is totally enclosed, and with adequate lead shielding of the E-Beam trailer, radiation monitoring did not reveal any OSHA compliance problems. Most equipment of this nature is regulated at a state level (for example, X-ray and other medical and laboratory equipment). Relevant standards for protection against radiation are included in the NRC regulations of 10 CFR Part 20. These standards are designed to limit radiation hazards caused by NRC-licensed activities. The regulations apply to all NRC licensees regardless of the type or quantity of radioactive material possessed or the type of operations conducted. These regulations require that (1) levels of radiation and dose be "as low as is reasonably achievable," and (2) radiation exposure limits for worker and public protection in 10 CFR Part 20 be met. Additional state-specific requirements should also be considered.

### 4.10.1 State and Community Acceptance

Because few applications of the E-Beam technology have been attempted beyond the bench or pilot scale, limited information is available to assess state and community acceptance of the technology. During the SITE demonstrations at the NBVC and the Savannah River Site, more than 100 people from regulatory agencies, nearby universities, and the local community attended Visitors' Day to observe demonstration activities and ask questions pertaining to the technology. The visitors expressed no concerns regarding operation of the E-Beam system.